Received: 10 October 2017 | Revised: 13 January 2018 | Accepted: 13 January 2018
DOI: 10.1002/mmce.21250

RESEARCH ARTICLE

WILEY INTERNATIONAL JOURNAL OF RF AND MICROWAVE COMPUTER-AIDED ENGINEERING

A miniaturized printed monopole antenna for 5.2-5.8 GHz WLAN applications

Farouk Chetouah[1] | **Salih Aidel**[2] | **Nacerdine Bouzit**[1] | **Idris Messaoudene**[2,3]

[1] Laboratoire d'Instrumentation Scientifique, Département d'électronique, Faculté de Technologie, Université Ferhat Abbas, 19000 Sétif, Algeria

[2] Laboratoire d'Electronique et des Télécommunications Avancées, université de Bordj Bou Arréridj, Algérie

[3] Ecole Nationale Supérieure d'Informatique (ESI ex. INI), BP 68M, Oued Smar, Algiers, Algeria

Correspondence
Farouk Chetouah, Département d'électronique, Faculté de Technologie, Laboratoire d'Instrumentation Scientifique, Université Ferhat Abbas, Sétif, Algeria 19000.
Email: chetouah.f@gmail.com

Abstract

In this article, a new design of a compact printed rectangular antenna for wireless local area network (WLAN) applications in 802.11a is investigated. The defected ground structure (DGS) technique is successfully used to reduce the ground plane by cutting a large slot to achieve significant miniaturization. The ground plane structure consists of inverted 'L' shape. The rectangular radiating element has a size of 6 × 5 mm^2 and is connected to a microstrip transmission feed line. The simulated and measured resonance frequency of the single-band antenna is approximately 5.8 GHz and may cover an impedance bandwidth of 1 GHz for the measurement and 1.65 GHz for the simulation. The simulated and the measured data are in good agreement. The proposed antenna is very compact (10 × 6 mm^2) and its impedance bandwidth is suitable for the 5.2-5.8 GHz WLAN communication systems.

KEYWORDS

compact antennas, DGS structures, miniaturized antennas, WLAN applications

1 | INTRODUCTION

NOWADAYS, the growing use and demand for various wireless communication devices in various fields, such as medicine, military, or aeronautics, motivate the manufacturers to develop continuously these wireless communication systems. In the same context, this technology has known considering progress in recent years in microwave RF circuits. However, the antenna still occupies the largest volume in the communication system chain; this means an increase in the overall size makes the implementation in small areas difficult.

For several decades, the antenna designers have investigated to miniaturize the antennas without losing their good performance in terms of gain or bandwidth. Several techniques have been proposed to reduce the size of antennas such as, loading with very high permittivity dielectric approach,[1–5] and using inductive or capacitive elements.[6–9]

In spite of the weakness that resides in its narrow bandwidth, microstrip antennas remain heavily used in wireless communication networks because of its low manufacturing cost and simplicity of design.[10] Many forms of radiating element have been used by manufacturers to achieve the best antenna's performance. However, the rectangular shape is the most dominant since it provides 2 degrees of freedom to adjust the antenna performance. In reference,[11] a microstrip antenna with dimension of 25 × 19 mm^2 has been used for tri-band applications by etching the patch with H-shaped slot. Another tri-band antenna has been fabricated with dimension of 30 × 30 mm^2 in,[12] but in this case with an inverted L shape slotted in the patch antenna.

The defected ground structure (DGS) is another way to achieve miniaturization and reduce the antenna size.[13,14] In the literature, there have been a number of approaches using the DGS miniaturization technique. Different shapes have been etched in the ground, some investigations can be cited like the use of a Co-Planar Waveguide (CPW) fed slot antenna with an inverted U-shaped stub in the ground plane with dimensions of 18 × 18 mm^2 that has been presented in.[15] This antenna operates at 2 resonant frequencies including 2.4 and 5.8 GHz. In reference,[16] a dual band antenna has been designed with dimension of 20 × 25 mm^2 for 2.4/5.2/

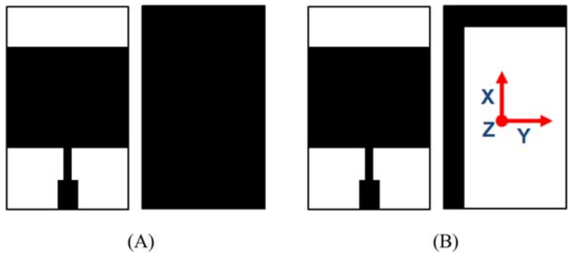

FIGURE 1 The design of the antenna for; (A) case1, (B) case2

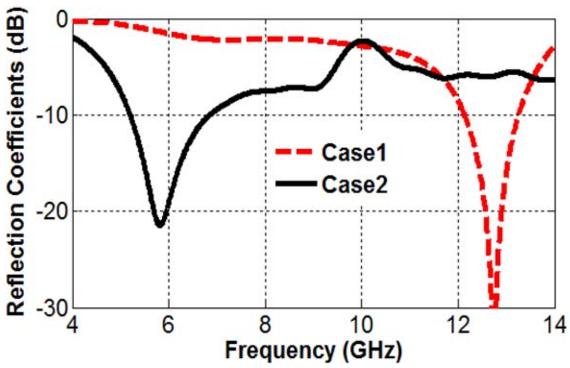

FIGURE 2 Simulated reflection coefficients for the 2 cases

5.8 wireless local area network (WLAN) applications with an E-shaped slot defected in the ground plane. A new approach for compact tri-band antenna design has been proposed in,[17] by loading 2 miniaturized edge resonators (with L and E shapes). In reference,[18] the shorting circuit technology has been used for the miniaturization of dual-band antenna operating at 2.4/5.8 GHz for WLAN applications.

In this work, a very small and compact printed rectangular monopole antenna is presented. The total antenna size is 10 × 6 mm^2 and consists of a rectangular patch and an inverted 'L' ground plane fed by a microstrip transmission line. The DGS structure technique is used to achieve the miniaturization.

2 | ANTENNA DESIGN AND SIMULATED RESULTS

2.1 | Theoretical consideration and antenna design

The prototype initially consists of a rectangular patch antenna printed on a dielectric substrate with FR-4 (Fire

TABLE 1 Simulated results of 2 antennas cases

Ant.	f_r (GHz)	Bandwidth (GHz)	BW %(GHz)	Gain/Total Efficiency (dBi/%)
Case1	12.74	12.13 – 13.25	8.82(1.12)	4.58/70.62
Case2	5.82	5.2 – 6.85	28.4(1.65)	2.34/97.55

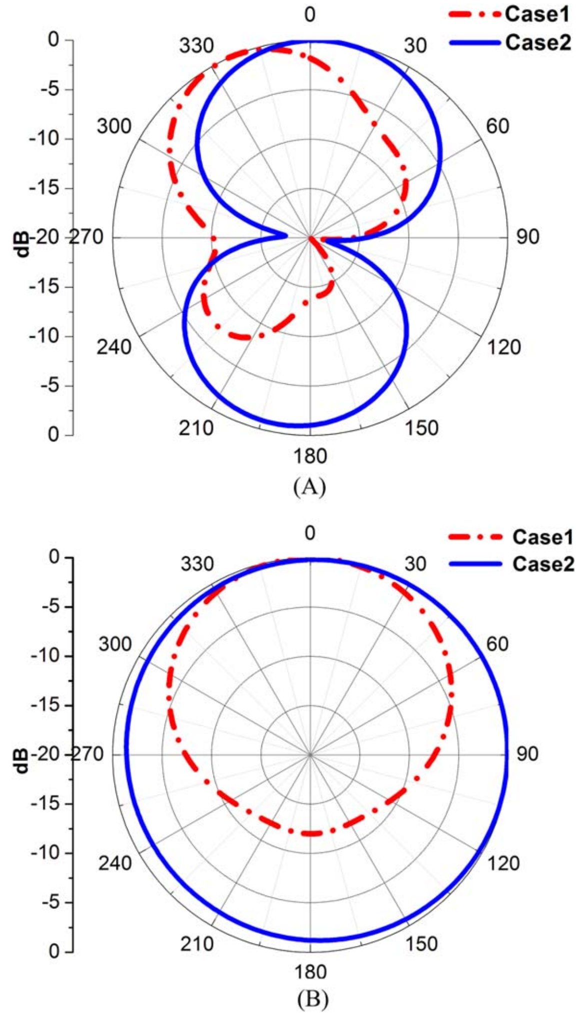

FIGURE 3 Simulated radiation pattern for the 2 cases in; (A) XZ-plane, (B) YZ-plane

Retardant) material with a relative dielectric constant ε_r=4.4, a thickness h = 1.6 mm and a loss tangent tanδ = 0.02. The feed line and the full ground plane (GND) are printed above and below the substrate, respectively, as illustrated in Figure 1A. To achieve the antenna miniaturization, the same antenna structure is studied with a partially printed ground plane (with inverted-L shape), as shown in Figure 1B.

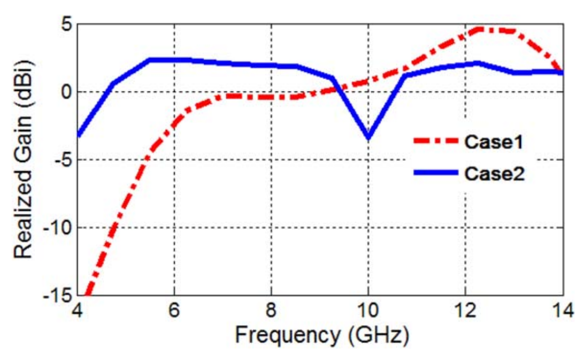

FIGURE 4 Simulated realized gain for the 2 cases

INTERNATIONAL JOURNAL OF
RF AND MICROWAVE
COMPUTER-AIDED ENGINEERING

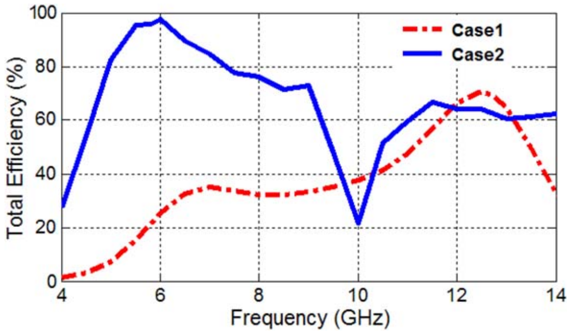

FIGURE 5 Simulated efficiency for the 2 cases

The details of the 2 cases are as follow:

- **Case1**: a rectangular patch antenna with a full ground plane.
- **Case2**: a rectangular patch antenna with a DGS structure (with inverted-L shape).

To calculate analytically the resonance frequency of the dominant mode, the formula cited by C. Balanis in[19] is applied:

$$f(\text{case1}) = \frac{C}{2W\sqrt{\varepsilon_r}} \tag{1}$$

where C is the celerity, W is the width of the radiating element, and ε_r is the relative permittivity of the substrate.

The obtained frequency value is around 12 GHz.

The structure in Figure 1A is a conventional patch antenna that resonates at a half wavelength (λ/2), while the same antenna resonates at approximately a quarter wavelength (λ/4) when the ground plane is reduced to an inverted-L shape (Figure 1B). This explains that the resonant frequency in case1 is almost the double of that obtained in case2 as demonstrated in Figure 2.

For the monopole antenna with a modified ground plane, the resonant frequency can be given by the following expression[20]:

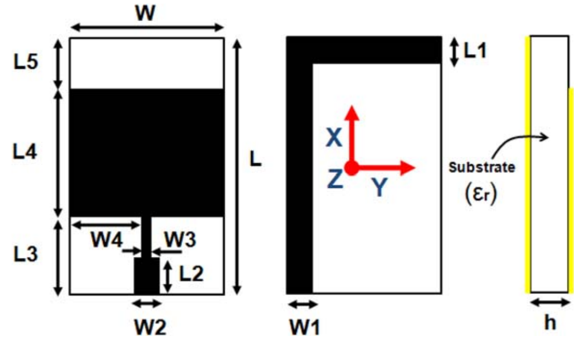

FIGURE 7 Geometry of the final design

$$f(\text{case2}) = \frac{C}{4W\sqrt{\varepsilon_r}} = \frac{f_r(\text{case1})}{2} \tag{2}$$

The new calculated value of the resonant frequency is closed to 5.96 GHz.

2.2 | Numerical analysis

To compare the performance of different antenna cases, the 2 designs were simulated using CST Studio software. All the electromagnetic characteristics (reflection coefficient, bandwidth, radiation pattern, gain, and radiation efficiency) are analyzed and discussed in this section.

The reflection coefficient of the 2 cases is depicted in Figure 2. From these curves, the performances of the antennas, in terms of the resonant frequency and the spectrum bandwidth are extracted and listed in Table 1. It can be seen from this table that the operating frequency of the case2 design is shifted to lower frequencies compared with the initial design, from 12.1–13.3 to 5.2–6.8 GHz. The miniaturization factor is identified by 2.18. It is also noted in Table 1 that the bandwidth is further increased from 1.12 to 1.65 GHz with a difference of 531 MHz. This enhancement is due to the effect of the input impedance and current flow of the antenna.

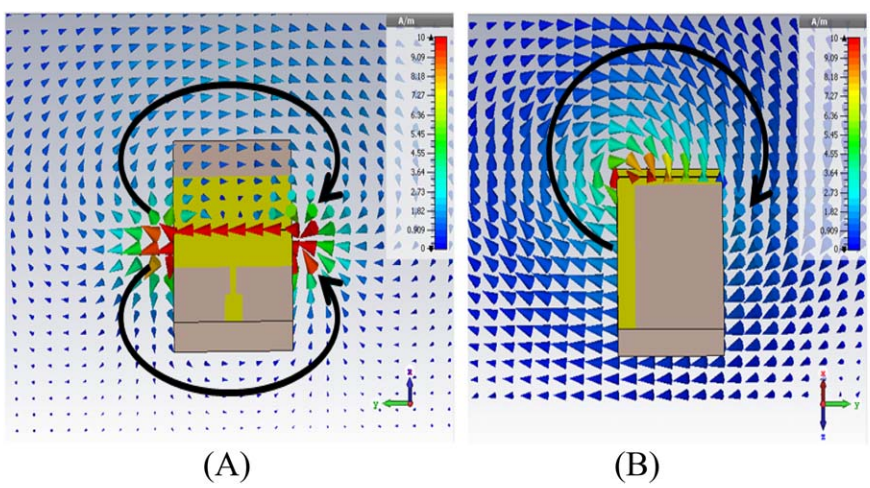

FIGURE 6 Simulated magnetic field distribution for the: (A) case1 at 12.7 GHz, and (B) case2 at 5.8 GHz

TABLE 2 The optimal dimensions of the proposed antenna

Parameters	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
L	10	L1	1	L2	1.5
L3	3	L4	5	L5	2
W	6	W1	1	W2	1
W3	0.4	W4	2.8	h	1.6

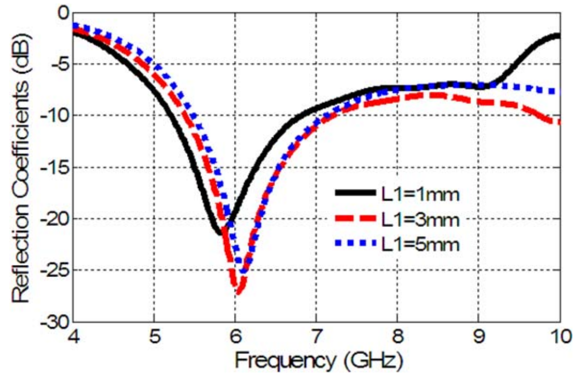

FIGURE 8 Effect of L1 parameter on the reflection coefficient

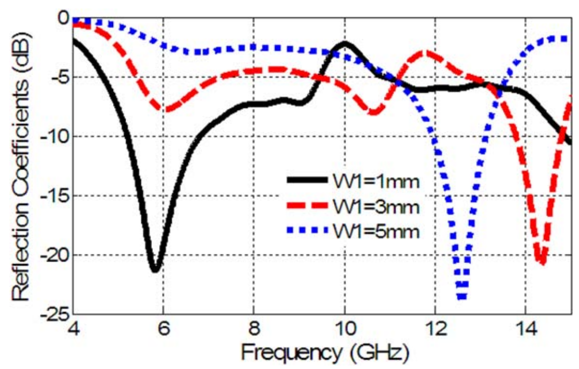

FIGURE 9 Effect of W1 parameter on the reflection coefficient

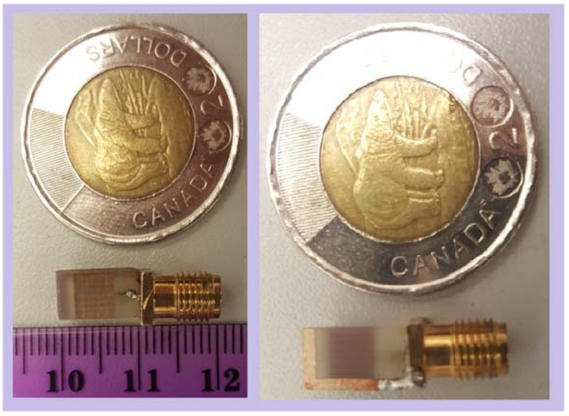

FIGURE 10 Photograph of the fabricated prototype

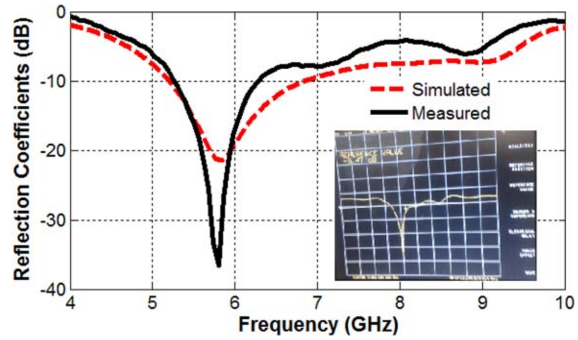

FIGURE 11 Simulated and measured reflection coefficient of the proposed antenna

The simulated radiation patterns of the both antennas are plotted in Figure 3 at their resonance frequencies (at 12.7 GHz for case1 and at 5.8 GHz for case2). From this

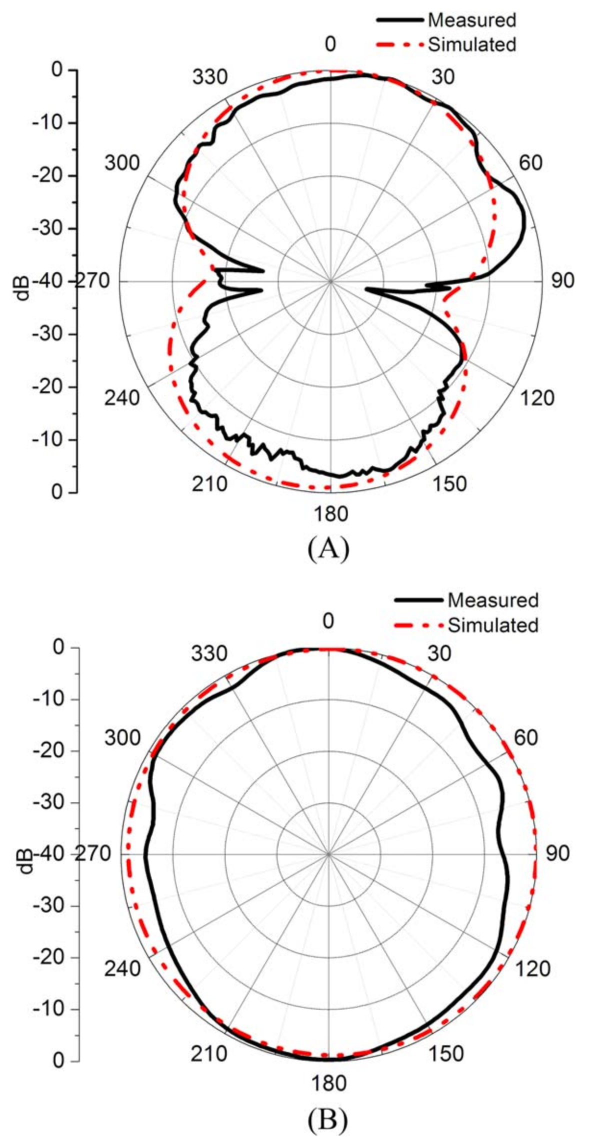

FIGURE 12 Simulated and measured radiation patterns at 5.8 GHz in; (A) XZ-plane, (B) YZ-plane

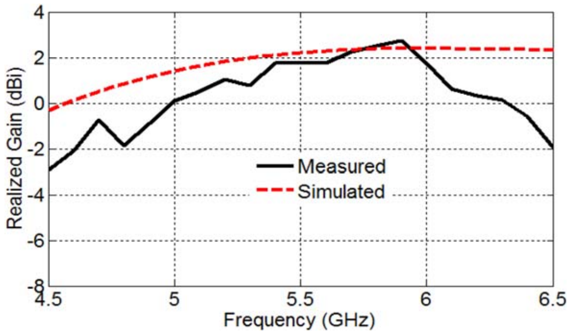

FIGURE 13 Simulated and measured realized gain of the proposed antenna

figure, it can be seen that the radiation curve in case2 is improved compared with the first case.

Figures 4 and 5 show the simulated gain and the total efficiency for both cases, respectively. Through the curves in Figure 4 it can be observed that the gain in case2 is 2.34 dBi at the frequency of 5.8 GHz and almost divides in 2 compared with the initial case. From the Figure 5, the maximum efficiency for the case1 is 70.62% at the frequency of 12.5 GHz and is 97.55% at the frequency 6 GHz for the case2. This increase is explained by the configuration of the monopole antenna, where the substrate dielectric loss does not play a major role.

The magnetic field distribution of the original and new design between the 2 conductors is addressed and plotted in Figure. 6 at their resonance frequencies. The magnetic field distribution is homogeneous in Figure 6A, the field lines emerge from 1 side of the substrate and move towards the other end, propagating at the top and the bottom of the patch towards the global ground plane. On the other hand for the partial ground plane (Figure 6B), the field lines take only 1 direction, with a long path, thus the wavelength increases, which explains the miniaturization by the DGS technique.

The optimal dimensions of the final antenna are presented in Figure 7 and summarized in Table 2.

2.3 | Effect of the GND size

Before carrying out the fabrication of the prototype, a performance analysis of the proposed antenna was carried out to show the best optimization results. The same software is used to study the effect of inverted L-shaped ground plane geometry (L1 and W1 parameters) on the antenna performance.

Figures 8 and 9 show the effect of the length and width of the inverted L-shaped ground plane on the reflection coefficient. It can be seen from these curves that to obtain a resonance frequency centered at 5.8 GHz (dedicated to the WLAN application), the length L1 = 1 mm and the width W1 = 1 mm should be chosen. It is also noted that the effect of the width W1 is greater than the length L1, on the reflection coefficient of the proposed antenna.

3 | MEASURED RESULTS AND DISCUSSION

To analyze experimentally the electromagnetic characteristics of the proposed antenna design, the final antenna design was fabricated (Figure 10 shows the photograph of the fabricated

TABLE 3 Comparison between the proposed antenna and the recent antenna designs

References	f_r/Gain (GHz/dBi)	Bandwidth (GHz)	Size including GND (mm^2)	Wavelength at the lowest frequency
21[a]	5.6/8.18	5.2–6.1	40 × 40	0.746 × 0.746 λ_0
22[a]	5.1/-	4.7–6.2	20 × 20	0.34 × 0.34 λ_0
23[b]	6.2/1.8	5 −7.2	15 × 15	0.31 × 0.31 λ_0
24[b]	5.2/8.2	5 – 5.2	36 × 30	0.624 × 0.52 λ_0
25[a]	5.8/14	5 – 6	23 × 23	0.444 × 0.444 λ_0
26[b]	5.2/1.71	5.1–5.4	24 × 16	0.416 × 0.277 λ_0
27[a]	5/6.5	4.8 – 6.6	$\pi (32)^2$	0.945 × 0.945 λ_0
28[a]	5.8/5.1	5.1–6.83	11 × 13	0.213 × 0.251 λ_0
29[b]	6.3/<0	6.1–6.5	11 × 15	0.231 × 0.315 λ_0
30[a]	5.8/3.1	5.4–6	13 × 19.8	0.251 × 0.383 λ_0
This work	5.8/2.5	5.2–6.2	10 × 6	0.193 × 0.116 λ_0

[a]Single band.
[b]Dual or multi-band.

prototype) and tested by using an Agilent 8719ES Vector Network Analyzer.

The simulated and measured reflection coefficients of the proposed antenna are plotted together in Figure 11. From this figure, it can be seen that the rectangular monopole antenna provides an impedance bandwidth between 5.26 and 6.28 GHz for the measured results (for reflection coefficient <–10 dB) and between 5.2 and 6.85 GHz for the simulated ones.

The radiation patterns of the proposed design are calculated and measured in the 2 principal planes (XZ and YZ-plane) at the central frequency 5.8 GHz and depicted in Figure 12. The radiation behavior of the antenna is almost bidirectional in the XZ-plane and omnidirectional in the YZ-plane.

In addition, Figure 13 shows the realized gain of the proposed antenna obtained from the simulation and measurements. From this curve, it can be seen that the realized gain is almost stable in the operating frequency band and the maximum gain value provided by the proposed antenna is about 2.5 dB at the resonant frequency of 5.8 GHz.

4 | COMPARISON WITH RECENT ANTENNA DESIGNS

In this section, the proposed antenna structure is compared (bandwidth vs. size) with existing 5.2/5.8 WLAN single/dual-band antenna designs recently published (from the measured reflection coefficient <–10 dB).

Table 3 shows a comparison between the proposed antenna and other recent antenna designs. From this table, it can be concluded that the proposed antenna is the most compact compared with the others, and provides a wide bandwidth of 1 GHz that covers the WLAN band in 802.11a.

5 | CONCLUSION

In this study, a new very compact printed rectangular monopole antenna has been designed and fabricated. The etched rectangular slot represents a reduction of 75% from the area of the printed ground plane that provides a high miniaturization. The measured results have shown a wide bandwidth of 1 and 1.65 GHz for the simulated ones (for S_{11} <–10 dB). The antenna impedance bandwidth covers the band from 5.2 to 6.2 GHz. The size of the proposed antenna is 6 ×10 mm^2 printed on 1.6-mm thickness FR-4 material substrate. The measured and simulated results are in good agreement. With these characteristics, the proposed design can be suitable for 5.2–5.8 GHz WLAN applications.

ACKNOWLEDGMENT

The authors would like to thank the Institut National de la Recherche Scientifique (INRS), Montreal, Canada (particularly Prof. T. A. Denidni and M. A. Meriche) and the École Militaire Polytechnique, Algiers, Algeria (particularly Misters A. Maali, A. Nouri, and B. Rekioua) for theirs helps during the measurements of the fabricated prototypes.

ORCID

Farouk Chetouah http://orcid.org/0000-0001-8321-0895

REFERENCES

[1] Volakis JL, Chen C-C, Fujimoto KY. *Small Antennas: Miniaturization Techniques and Applications*, USA: McGraw-Hill Education; **2010**.

[2] Chetouah F, Bouzit N, Messaoudene I, Aidel S, Belazzoug M, Hammache B. Miniaturized rectangular dielectric resonator antenna for WCS standards. In: 12th International Conference on Innovations in Information Technology (IIT'16), U. A. Emirates, 28–30 November **2016**.

[3] Fiedziuszko SJ, Hunter IC, Itoh T, et al. Dielectric materials, devices, and circuits. *IEEE Trans Microw Theory Tech.* **2002**;50 (3):706–720.,

[4] Ponchel F, Remiens D, Ghalem A, Lasri T. Ferroelectric thin films working at microwave frequency for reconfigurable devices on silicon substrate: performances comparison between BST, PST. *Int J Mater Eng Innov.* **2014**;5(4):327–335.

[5] Leung KW, Lo HY, So KK, Luk KM. High-permittivity dielectric resonator antenna excited by a rectangular waveguide. *Microw Opt Technol Lett.* **2002**;34(3):157–158.

[6] Braham Chaouche Y, Bouttout F, Messaoudene I, Pichon L, Belazzoug M, Chetouah F. 'Design of reconfigurable fractal antenna using pin diode switch for wireless applications. In: 16th Mediterranean Microwave Symposium (MMS'16), 14–16 November **2016**.

[7] BorhaniRezaei MP, Valizade A. Design of a reconfigurable miniaturized microstrip antenna for switchable multiband systems. *IEEE Antennas Wireless Propag Lett.* **2015**;15:822–825.

[8] Chaimool S, Pinsakul A, Akkaraekthalin P. Patch antenna miniaturization using artificial magneto-dielectric metasubstrate. *International Symposium on Antennas and Propagation (ISAP).* 29 October-2 November **2012**.

[9] So KK, Wong H, Luk KM, Chan CH. miniaturized circularly polarized patch antenna with low back radiation for GPS satellite communications. *IEEE Trans Antennas Propag.* **2015**;63(12): 5934–5938.

[10] Nalini K, Sai Suneel A, Sridevi SB. E-Shape patch antenna for millimeter wave communication. *Int J Eng Sci Res.* **2013**;04 (Special Issue 01):1199–1207.

[11] Kumar A. A compact h-shaped slot triple-band microstrip antenna for WLAN and WiMAX applications. In: IEEE Annual India Conference (INDICON), 16–18 December **2016**.

[12] Kaur A, Kaur A, Singh Dhillon A, Sidhu E. Inverted L shape slotted microstrip patch antenna for IMT, WiMAX and WLAN

applications. In: International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), Chennai, India, 23–25 March 2016.

[13] Salih AA, Sharawi MS. Highly miniaturized dual band patch antenna. In: 10th European Conference on Antennas and Propagation (EuCAP), 10–15 April 2016.

[14] Wang D, Wong H, Chan CH. Small patch antennas incorporated with a substrate integrated irregular ground. *IEEE Trans Antennas Propag.* **2012**;60(7):3096–3103.

[15] Mohapatra S, Raghavan S, Sahu S, Das S, Ranjan Panda J. A compact coplanar waveguide-fed slot antenna with an inverted U- shaped stubs for WLAN application", In: International Conference on Communication and Signal Processing (ICCSP), India 6–8 April 2016.

[16] Bhasker, Chandan MK, Prasad RK. Design of monopole antenna with defected ground for WLAN application. In: International Conference on Emerging Trends in Electrical, Electronics and Sustainable Energy Systems (ICETEESES–16), 11–12 March 2016.

[17] Hu W, Wu J-J, Zheng S-F, Ren J. Compact ACS-fed printed antenna using dual edge resonators for tri-band operation. *IEEE Antennas Wireless Propag Lett.* **2015**;15:207–210.

[18] Liu H, Zhang L, Pan J, Liu C, Lin Z. A novel dual-band antenna for WLAN application. *Progress in Electromagnetic Research Symposium (PIERS), China.* August **2016**;8–11.

[19] *Antenna Theory: Analysis Design, Third Edition, Constantine A. Balanis, Chapter 14: Microstrip Antennas*, John Wiley & Sons, Inc., **2005**:826–831.

[20] Yang J, Wang H, Lv Z, Wang H. Design of miniaturized dual-band microstrip antenna for WLAN application. *Sensors.* **2016**; 16(7):983

[21] Elsdon M, Yurduseven O, Dai X. Wideband metamaterial solar cell antenna for 5 GHz Wi-Fi communication. *Prog Electromagn Res C.* **2017**;71:123–131. Vol.

[22] Ojaroudi Y, Ojaroudi N, Ghadimi N. Circulary polarized microstrip slot antenna with a pair of spur-shaped slits for WLAN applications. *Microw Opt Technol Lett.* **2015**;57(3):756–759.

[23] Alibakhshi-Kenari M. Miniaturized printed monopole antenna with applying the modified conducteur-backed plane and three embedded strips based on CPW for multi-band telecommunication devices. *Int J Microw Wireless Technol.* **2016**;8(08):1–5

[24] Yang H-L, Yao W, Yi Y, Huang X, Wu S, Xiao B. A dual-band low-profile metasurface-enabled wearable antenna for WLAN devices. *Prog Electromagn Res C.* **2016**;61:115–125.

[25] Liu L, Li Y, Zhang Z, Feng Z. Compact helical antenna with small ground fed by spiral-shaped microstrip line. *Electron Lett.* **2014**;50(5):336–338.

[26] Chakraborty U, Kundu A, Chowdhury SK, Bhattacharjee AK. Compact dual-band microstrip antenna for IEEE 802.11a WLAN Application. *IEEE Antenna Wireless Propag Lett.* **2014**;13:407–410.

[27] Wong H, So KK, Gao X. Bandwidth enhancement of a monopolar patch antenna with V-shaped slot for car-to-car and WLAN communications. *IEEE Trans Vehic Technol.* Mar. 2016;65(3):1130–1136.

[28] Liu W-C, Hu Z-K. Broadband CPW-fed folded-slot monopole antenna for 5.8 GHz RFID application. *Electron Lett.* **2005**;41 (17):937–939.

[29] Alam MJ, Faruque MRI, Islam MT. Split quadrilateral multiband microstrip patch antenna design for modern communication system. *Microw Opt Technol Lett.* **2017**;59(7):1530–1538.

[30] Pandeeswari R, Raghavan S. Meandered CPW-fed hexagonal split-ring resonator monopole antenna for 5.8 GHz RFID applications. *Microw Opt Technol Lett.* **2015**;57(3):681–684.. No.

AUTHOR BIOGRAPHIES

Farouk Chetouah received the Engineer degree in Electronics from the University Ferhat Abbas (UFAS) of Setif in 2002. He also received his Magister degree in Instrumentation from UFAS University in 2012. He is pursuing his PhD diploma at the same university. Since 2003, he has been a teacher in National Institute of Professional Training of Bordj Bou Arréridj (INSFP-BBA1), Algeria. His research interests include a miniaturized antenna, planar antennas, microstrip Antennas (MSA), dielectric resonator antennas (DRA), and Ultra-Wideband Antennas (UWB).

Salih Aidel received the Engineer degree in Electronics from the National Polytechnic School of Algiers (ENPA), Algeria, in 1985. He obtained his Magister degree in Control and Communication Systems in 1990 from the University of Constantine (UMC), Algeria, and the Ph.D. degree in Electronics Engineering in 2011 from the University of Setif (UFAS), Algeria. He joined the Electronics Department, University of Setif, Algeria, in 1985, then he joined in 2000 the Electronics Department, University of Mohamed Bachir El-Ibrahimi, Bordj Bou Arréridj (UBBA), Algeria, as an Assistant Professor. He is currently the director of the Electronics and Advanced Communications (ETA) Laboratory of the UBBA since 2015. He conducted many research projects in Machine-to-Machine Communications. His research interests include: Wireless Communications, Internet of Things, Microwave circuits design, Cryptography and Network Security.

nacerdine Bouzit was born in Setif, Algeria, and graduated as Electronics Engineer in 1985 from ENPA (National Polytechnic School) of Algiers, Algeria. In 2002, he obtained his PhD degree in Instrumentation from the University of Bordeaux, France at the Laboratory of Physique-Interaction-Onde-Matière (PIOM). Currently, he is Professor at the UFAS University of Setif. He was author and co-author of more than 30 scientific papers. His research interests include: dielectric materials and different characterization techniques, microstrip discontinuity modeling and microstrip antennas.

Idris Messaoudene received his PhD degree in Microwaves and Telecommunications from the University of Constantine, in 2014, and his Master degree in Networks and Telecommunication Technologies from the University of Bordj Bou Arréridj Algeria, in 2009. From February to October 2016, he was Senior Research Fellow and leader of the research team "Devices for Telecommunications" at the Research Centre in Industrial Technologies, Algeria. Since November 2016, he has been an Assistant Professor with Higher School of Computer Science, Algiers, Algeria. His research interests include dielectric resonator antennas, microstrip and printed antennas, UWB antennas, reconfigurable antennas, millimeter-wave antennas, beamforming and adaptive antenna arrays, antennas for MIMO systems, Electromagnetic Bandgap (EBG) structures, Metamaterials, Frequency selective surfaces (FSS), and numerical methods for electromagnetism analysis.

How to cite this article: Chetouah F, Aidel S, Bouzit N, Messaoudene I. A miniaturized printed monopole antenna for 5.2-5.8 GHz WLAN applications. *Int J RF Microw Comput Aided Eng*. 2018;e21250. https://doi.org/10.1002/mmce.21250